US Army Corps of Engineers
Waterways Experiment Station

Zebra Mussel Research Technical Notes

Section 1 — Environmental Testing Technical Note ZMR-1-33

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Influences of Zebra Mussels on Conditions at the Sediment-Water Interface

Background and purpose

One of the concerns over the invasion of zebra mussels in the Upper Mississippi River (UMR) system is the rapid colonization of these organisms in backwater regions with accompanying changes in water/sediment quality and habitat value. It is expected that zebra mussels will have a pronounced effect on the sediment and water column micro-environment after colonization. For instance, zebra mussels can graze seston (phytoplankton) and, because of their high densities, can filter water at tremendous rates, thereby transferring suspended particulate matter from the water column to the sediments (Reeders and de Vaate 1990). This process may have an important impact on food web dynamics, contaminant cycling, and water/sediment quality (Bruner, Fisher, and Landrum 1994; Effler and Siegfried 1994; Holland 1993; Leach 1993; Nichols and Hopkins 1993).

Zebra mussel grazing also results in increased light penetration, which could affect epipelic community productivity (Griffiths 1993) and benthic trophic levels. Excretion of feces and pseudofeces on the sediment surface (Ten Winkel and Davids 1982) could, in turn, affect sediment chemistry and nutrient dynamics at the sediment-water interface. Thus, the colonization of zebra mussels on sediments in the UMR may affect ecosystem dynamics in backwater regions.

This technical note summarizes research that was conducted to examine the changes in sediment and overlying water chemistry that occur due to zebra mussel colonization.

Additional information

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Experimental approach

Laboratory microcosms consisted of 4-L jars measuring 20 cm in height and 17 cm in diameter. Twelve replicate control microcosms contained sediment and lake water while 12 replicate experimental microcosms contained sediment, lake water, and a zebra mussel density of 10,000 individuals/m^2. Surface sediment, collected with a ponar sampler in the Finger Lakes backwater region of the UMR (located immediately downstream of Lock and Dam 4), was mixed homogeneously before dispensing 1.5 L into each microcosm. Water in each microcosm (about 1.5 L) was flushed via a peristaltic pump system approximately twice a day throughout the study with fresh lake water (seston = ~10 mg/L; pH = 9.1, conductivity = 282 μS; alkalinity = 173 mg $CaCO_3$/L), obtained daily from Eau Galle Reservoir (Spring Valley, WI).

Assembled microcosms were placed in a temperature-controlled water bath (about 18 °C), gently aerated with air stones throughout the study to maintain aerobic conditions, and allowed to equilibrate for about 2 weeks before the introduction of zebra mussels. Zebra mussels used in the study had a median length of 18 mm. Approximately 175 individuals were placed gently on the sediment surface of each experimental microcosm. The duration of the study following introduction of zebra mussels was 4 weeks.

At 2-week intervals, six randomly chosen experimental and control microcosms were sacrificed for analysis of overlying water quality and vertical changes in sediment chemistry. Overlying water was collected 1 cm above the sediment surface with a 60-cc syringe and immediately filtered through a 0.45-μm membrane filter. Samples were analyzed for ammonium nitrogen, nitrate-nitrite nitrogen, and soluble reactive phosphorus using standard analytical procedures (American Public Health Association 1992).

A 4-cm-diam sediment core was then collected from each system. The sediment core was transferred to a glove box that was completely purged of oxygen with nitrogen gas to maintain anaerobic conditions of the sediment. The core was sectioned at 5-mm intervals down to the 10-mm depth, and then at 10-mm intervals to a depth of 40 mm (i.e., five subsections). The subsections were placed in a 20-ml centrifuge tube, purged with nitrogen gas, and centrifuged at 3,000 rpm's for 1 to 2 hr to separate pore water from the sediment. Under a nitrogen atmosphere, the pore water was removed via a syringe, immediately filtered through a 0.45-μm membrane filter, and analyzed for ammonium nitrogen, nitrate-nitrite nitrogen, and soluble reactive phosphorus. The remaining sediment from each section was analyzed for sediment extractable phosphorus (Olsen and Sommers 1982) and exchangeable ammonium nitrogen (Bremner 1965).

Results and discussion

No significant differences in overlying water and sediment concentrations as a function of date were noted in experimental and control microcosms (t-test; Statistical Analysis System (SAS) 1988), so all data were combined for analysis. Concentrations of ammonium nitrogen, nitrate-nitrite nitrogen, and soluble reactive phosphorus of the overlying water were significantly greater in experimental than control microcosms (t-test; SAS 1988) (Figure 1).

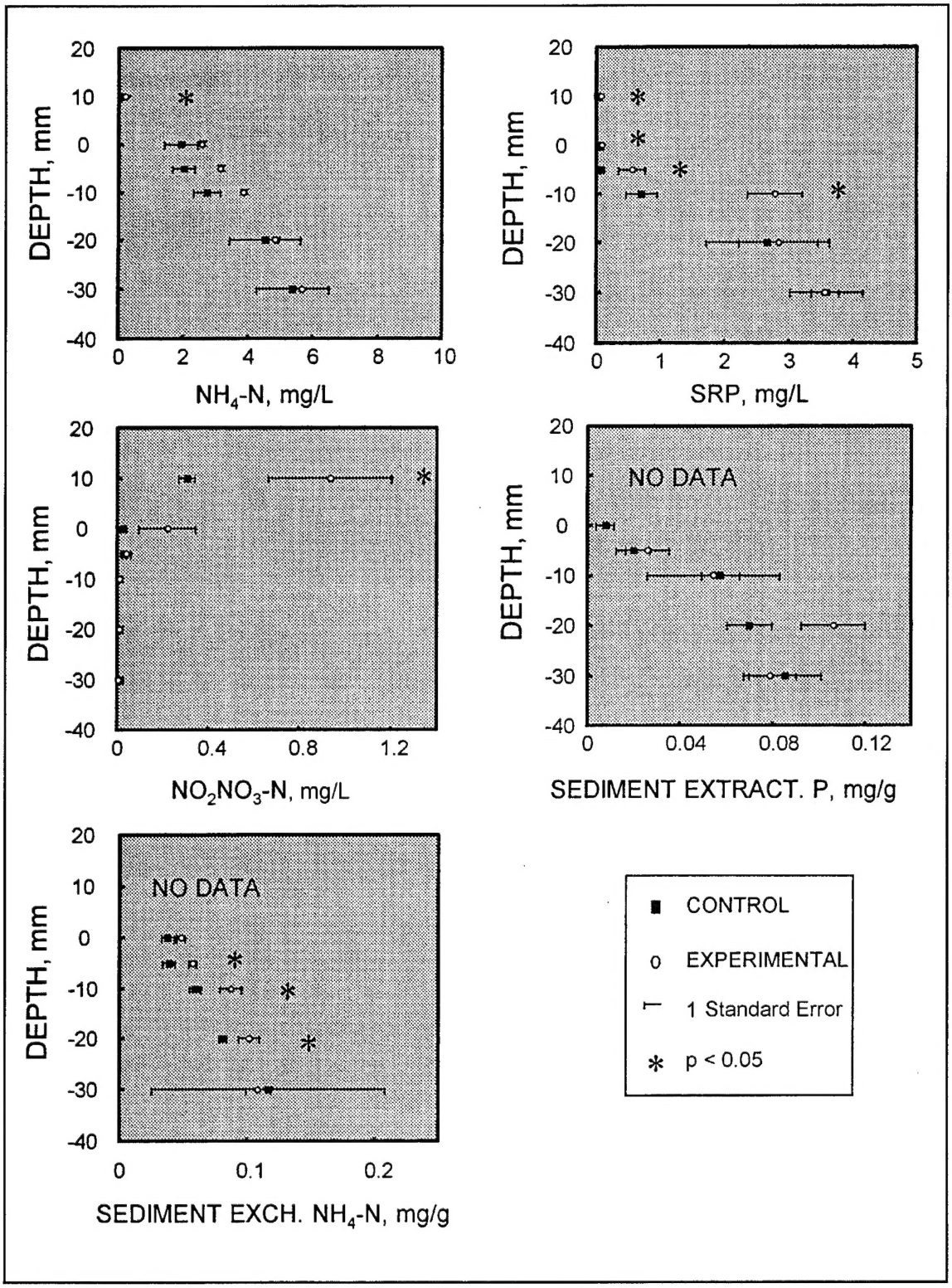

Figure 1. Variations in mean concentrations of ammonium nitrogen (NH_4-N), nitrate-nitrite nitrogen (NO_2NO_3-N), and soluble reactive phosphorus (SRP) in the overlying water and sediment pore water, and variations in sediment exchangeable ammonium nitrogen (EXCH. NH_4-N) and extractable phosphorus (EXTRACT. P) in experimental and control microcosms. Negative depths indicate depths in the sediment below the sediment-water interface

In the sediment pore water, concentrations of ammonium nitrogen increased while nitrate-nitrite nitrogen decreased, as a function of sediment depth in both experimental and control microcosms (Figure 1). However, no differences in pore water concentrations of these variables as a function of treatment were noted, suggesting that zebra mussel activities had little influence on nitrogen species in the sediment pore water. Exchangeable ammonium nitrogen concentrations in the sediment increased in a linear fashion with increasing sediment depth in both experimental and control microcosms. Experimental microcosms exhibited significantly greater concentrations of exchangeable ammonium nitrogen in the sediments at depths greater than 5 mm. In the upper 5 mm of sediment, however, experimental and control microcosms exhibited no significant differences in exchangeable ammonium nitrogen concentrations.

Concentrations of soluble reactive phosphorus in the pore water were significantly greater in experimental than control microcosms in the upper 10 mm of sediment (Figure 1). However, this trend was not observed for extractable sediment phosphorus concentrations. While extractable sediment phosphorus increased with increasing sediment depth in both experimental and control microcosms, there were no differences between treatments.

Our results suggest that zebra mussel influences on nutrient chemistry were most pronounced in the overlying water. Coincident with the occurrence of zebra mussels in microcosms were elevated concentrations of ammonium nitrogen, nitrate-nitrite nitrogen, and soluble reactive phosphorus in the overlying water. Sediment-related changes in nutrient concentrations in the surface sediments as a result of zebra mussel activity were not apparent, with the exception of increased soluble reactive phosphorus in the pore water of the surface sediments.

Elevated concentrations of nutrients in the overlying water of experimental systems can be associated with at least two factors. First, feeding activity and excretion may result in the breakdown of particulate matter into soluble fractions that accumulate at the sediment-water interface. Second, zebra mussel growth may have been inhibited at high density levels, resulting in a loss of biomass (negative growth rate) due to lack of an adequate food source to sustain growth. Densities of zebra mussels in the laboratory microcosms were very high relative to the flushing rate and food supply. Nichols (1993) suggested that a food supply of 3.2 g 1,000 individuals^{-1} day^{-1} in the form of green algae could maintain a positive growth rate under laboratory conditions. In this study, the seston supply to microcosms was an order of magnitude lower, at 0.2 g 1,000 individuals^{-1} day^{-1}. Although zebra mussels were living throughout the study, low food supply may have caused starvation and nutrient losses from their tissues.

The experimental design will be improved by adjusting zebra mussel densities to promote growth under prevailing available food supply. However, these results apply to conditions of growth stress in nature during periods of, for instance, extremely warm or cool temperatures, highly turbid water, low dissolved oxygen, or

temporary lack of food supply. More information is needed on nutrient dynamics at the sediment-water interface under conditions of favorable zebra mussel growth, as the production of feces and pseudofeces deposits under these conditions (Nichols 1993) may result in further modifications in nutrient pools at the sediment-water interface.

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